Design and Analysis of Micro strip Patch Antenna At 12 Ghz For Satellite Communication

M.Annapoorna, PG Scholar, Department of Communication Systems Engineering, Government college of Engineering – Salem-11, Tamil Nadu, India, mannapoorana@gmail.com

Dr.I.Kalphana, Assistant Professor, Department of Electronics and Communication Engineering, Government college of Engineering – Salem-11, Tamil Nadu, India, kalphanasenthil@gmail.com

Abstract Microstrip patch antennas are widely used in satellite communication because of their advantages like lightweight, compact design, ease of production, and versatility across frequencies, making them more efficient and cost-effective compared to conventional antennas. A rectangular microstrip patch antenna is presented in this paper for Ku-band microstrip patch antenna to operate at 12 GHz satellite communication especially for satellite Internet access, broadcasting and direct-to-home, and satellite tracking and monitoring applications to achieve a precise -10 dB return loss to minimize reflections, maximize efficiency, and enhance the antenna & ability to effectively transmit and receive signals. Additionally, aim to get a value of VSWR less than 2 (S_{11}parameter) to confirm the antenna is well-matched to its transmission line, efficientlytransferring signal power and effectively radiating transmitted power into space. The suggested antenna is designed on a low-cost FR-4 substrate with a thickness of 1.6 mm. The patch has a length of 7.6 and a width of 5.1, with a 4.4 dielectric constant placed between the patch and a ground plane constructed of copper. The antenna was designed and simulated using the High-Frequency Structural Simulator (HFSS). This low-profile nature and simple configuration of the proposed high-gain antenna show the way to easy fabrication and make it appropriate for the application in satellite communication. The performance of the patch antenna has been scrutinized for different antenna parameters, such as return loss (S11), directivity, gain, bandwidth, VSWR, E-field, and H-field radiation pattern.

Keywords-ANSYS HFSS (high-frequency structure simulator), DBS (Direct Broadcast Satellites),DTH (Direct-to-Home Television), FSS (Fixed Satellite Service), GNSS (Global Navigation Satellite Systems)MSS (Mobile Satellite Service), VSWR (Voltage Standing Wave Ratio).

I. INTRODUCTION

Antennas are essential for enabling information transfer over long distances in the field of modern wireless communication.An antenna is a device that converts electrical signals to electromagnetic waves and vice versa. It is an essential component in any wireless communication system, including satellite communication, where it facilitates the transmission and reception of data over long distances through space. An antenna can be defined as a device designed to radiate or receive electromagnetic waves effectively. It typically consists of conductive elements such as metal rods, wires, or printed circuits, which interact with the electromagnetic field to achieve the desired transmission or reception. This paper focuses on designing a rectangular microstrip patch antenna. Microstrip patch antennas are used because of how simple it is to produce microstrip patch structures. Microstrip analysis has become a complex research challenge. In the twenty-first century, research on microstrip antennas sought to reduce size while boosting gain, providing a broad bandwidth, various functions, and system-level integration. The need for broadband, low-profile, and small antennas has grown dramatically in recent years due to the widespread deployment of wireless communication technology. Because of its low profile, light weight, and affordable price, the microstrip patch antenna has been suggested as a solution to meet the requirements. Shapes like square, rectangular, circular, and elliptical. Because of their small size, microstrip antennas have found use in a variety of civilian and military applications, including radio-frequency identification (RFID), broadcast radio, mobile systems, and vehicle collision avoidance. Systems, satellite communications, surveillance systems, direction finding, radar systems, remote sensing, missile guidance, and others. This antenna is designed for Ku-band satellite communication, specifically targeting applications like satellite Internet access, broadcasting, direct-to-home services, and satellite tracking and monitoring. Microstrip patch antennas have become a cornerstone in satellite communication technology due to their unique combination

 DOI : 10.35291/2454-9150.2024.0332

of advantageous properties. These antennas are widely utilized in both ground-based and satellite-mounted systems to facilitate

Reliable and efficient communication links. This introduction outlines the fundamental aspects and applications of microstrip patch antennas in satellite communication.

TABLE 1: SATELLITE COMMUNICATION FREQUENCY RANGE

Band	Frequency range	Total bandwidth	Application
L	1 to 2 GHz	1	Mobile satellite service (MSS)
S	2 to 4 GHz	2	MSS, deep space research
C	4 to 8 GHz	4	Fixed satellite service (FSS)
X	8 to 12 GHz	4.5	FSS military, terrestrial earth exploration
Ku	**12 to 18 GHz**	**5.5**	**Broadcast satellite service**
K	18 to 26 GHz	8.5	FSS

The L band (1 to 2 GHz) is suitable for applications like GPS and mobile satellite services, offering good penetration through obstacles and a relatively large antenna size due to the lower frequency. However, its limited bandwidth restricts data transmission rates, making it less ideal for high-capacity communication. The S band (2 to 4 GHz) provides a balance between coverage and antenna size, commonly used in deep space communication and weather radar. While it offers better bandwidth than the L band, it still falls short of the Ku band in terms of data capacity and antenna compactness. The C band (4 to 8 GHz) is favored for its reliability in fixed satellite services, such as television broadcasting, but requires larger antennas compared to higher frequency bands and offers moderate bandwidth.

The X band (8 to 12 GHz) is used in military and radar applications, where higher data rates and good resolution are needed. Despite offering better performance than lower bands, it still results in larger antenna dimensions compared to the Ku band. The Ku band (12 to 18 GHz) stands out for its ability to support higher data rates and smaller antenna sizes, which are advantageous for applications requiring compact, high-performance antennas, such as satellite TV and broadband. The higher frequency of the Ku band allows for more precise and efficient designs, making it easier to integrate into devices with space constraints. Although the Ku band is more susceptible to atmospheric attenuation (e.g., rain fade) than lower bands, its higher bandwidth and the ability to use smaller patches give it a significant edge in modern communication systems.

The K band (18 to 26 GHz), while offering even higher data rates, comes with challenges such as severe atmospheric attenuation and the need for even smaller and more precise antenna designs, making it less practical for some applications compared to the Ku band. Overall, the Ku band offers an optimal balance of performance, size, and practical application for designing rectangular microstrip patch antennas, making it highly advantageous over the other frequency bands.

The antenna design process is carried out with the ANSYS High Frequency Structure Simulator (HFSS). ANSYS HFSS provides numerous advantages for designing microstrip patch antennas, which are vital in modern wireless communication systems. Its ability to deliver highly accurate electromagnetic simulations through numerical solutions of Maxwell's equations ensures precise predictions of antenna performance, including critical parameters like return loss, bandwidth, and radiation patterns. HFSS's advanced solver technology, such as the Finite Element Method (FEM), allows for detailed analysis of complex antenna structures, including those with intricate designs or high-frequency requirements. The software's capability to handle complex geometries and material properties is particularly beneficial for designing microstrip patch antennas with sophisticated shapes or multi-layer configurations. Additionally, HFSS's optimization tools enable users to refine antenna designs by adjusting parameters to meet specific performance goals, such as enhanced gain or bandwidth. Comprehensive analysis tools, including S-parameter analysis and radiation pattern visualization, provide a thorough understanding of the antenna's behavior. HFSS also integrates seamlessly with other engineering tools, facilitating a smooth workflow from design through simulation to optimization. Its support for various frequency ranges, detailed visualization capabilities, and robust documentation features further enhance its utility in designing high-performance microstrip patch antennas, ensuring that they meet the rigorous demands of modern applications.

A Wideband Corrugated Ridged Horn Antenna with Enhanced Gain and Stable Phase Center for X- and Ku-Band Applications introduces a wideband corrugated ridged horn antenna designed for both X- and Ku-band applications. The antenna corrugated ridge structure enhances its gain and ensures a stable phase center across the operating frequency range. The study includes comprehensive simulation and experimental validation, showing that the proposed antenna achieves significant improvementsin bandwidth and gain, making it suitable for various satellite communicationapplications in 2019[2].High-EfficiencyStacked Shorted Annular Patch Antenna

DOI : 10.35291/2454-9150.2024.0332

Feed for Ku-Band SatelliteCommunications presents a high-efficiency stacked shorted annular patch antenna feeddesigned for Ku-band satellite communications and proposed a configuration that improves efficiency by stacking multiple annular patches andintroducing shorting posts to enhance the antenna gain and bandwidth. Thedesign methodology involves detailed electromagnetic simulations and prototypetesting, resulting in an antenna that demonstrates superior performance in termsof efficiency and radiation characteristics compared to conventional designs in 2016[1].Design and Analysis ofMicrostrip Patch Antenna for Satellite Communication presented a comprehensive design and analysis of a microstrip patch antenna aimed at satellite communication applications. The research involves the use of advanced simulation tools to optimize the antenna performance parameters. The study also includes a comparison with existing designs, showingthat the proposed antenna offers improved gain and bandwidth, making it aviable option for modern satellite communication systems in 2024 [4].Design of Micro Strip Stacked Patch

Antenna in C-Band for Satellite and Radar Communicationsproposes a microstrip stacked patch antenna designed for C-band applications in satellite and radar communications. The design involvesstacking multiple patch layers to enhance the bandwidth and gain. The studyincludes both simulation and experimental validation, demonstrating that theantenna performs well in the C-band frequency range with satisfactory radiationcharacteristics in 2019[5].

II. DESIGN METHODOLOGY

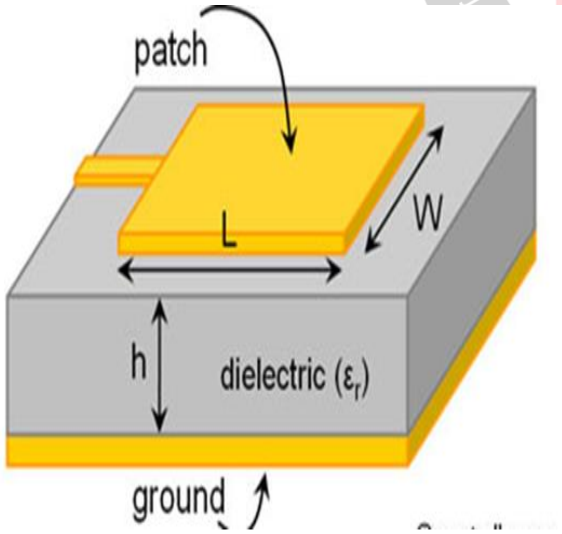

Fig.1: RECTANGULAR MICROSTRIP PATCH ANTENNA

In this paper, a rectangular patch is used to design a microstrip patch antenna because of its simplicity, ease of fabrication, and adaptability. Its straightforward design, consisting of a flat rectangular conductor mounted on a dielectric substrate with a ground plane, makes it easy to manufacture using standard printed circuit board (PCB) techniques. This design also results in a compact and lightweight antenna, ideal for integration into space-constrained devices like mobile phones and laptops. The antenna's dimensions can be adjusted to cover a wide range of frequencies, providing versatility for various applications, from low-frequency communications to higher-frequency radar systems. Additionally, its planar nature allows for easy integration with other circuit elements on a single PCB, simplifying the overall design and assembly process. The rectangular microstrip patch antenna is also cost-effective to produce due to its compatibility with mass-production methods. Overall, its combination of performance characteristics, customization options, and production efficiency makes it a popular choice for modern wireless communication systems.

A. *Feed Techniques*

The edge feed technique is used in this antenna design because itoffers significant advantages in designing microstrip patch antennas for Ku-band satellite communication compared to other feeding techniques such as coaxial probe feed, aperture-coupled feed, and proximity-coupled feed. One key benefit is its straightforward implementation, involving a direct connection of the microstrip line to the patch edge, which simplifies fabrication and reduces costs—critical factors for the high-volume production of satellite communication equipment. The planar nature of the edge feed is highly compatible with printed circuit board (PCB) technology, making it easier to integrate into compact and lightweight satellite communication systems. This technique also ensures excellent impedance matching and broad bandwidth, both essential for the high-frequency requirements of Ku-band communication, thereby enhancing signal quality and overall antenna efficiency. Additionally, the edge feed method minimizes radiation losses and spurious emissions, leading to improved performance and reliability in satellite communications. The ease of integration with other microwave components and circuits further enhances the versatility of the edge feed approach, making it a preferred choice for Ku-band applications where precision, performance, and efficiency are paramount.

III. DESIGN EQUATION OF RECTANGULAR MICROSTRIP PATCH ANTENNA AT

12GHz

$C = 3 \times 10^8$

$fo = 12$

GHz. $= 12 \times 10^9$Hz

$\epsilon\_r = 4.4$

 DOI : 10.35291/2454-9150.2024.0332

A. Design Formula

Width of the patch,

$$Width = \frac{c}{2f_o\sqrt{\frac{\varepsilon_R+1}{2}}} \quad 1$$

$$= \frac{3X10^8}{2X12X10^9\sqrt{(4.4+1)/2}}$$

w = 5.19647

$$\varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right]$$

$$= \frac{4.4+1}{2} + \frac{4.4-1}{2}\left[\frac{1}{\sqrt{(1+12(1.6/5.19)}}\right]$$

= 4.059

Length of the patch,

$$Length = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right) \quad 2$$

$$f(x) = \frac{3X10^8}{2X12\sqrt{4.059}} - (4.059+0.3)(\frac{5.19}{1.6} + 0.264)/(4.059-0.258)(5.19/1.6 + 0.8)$$

= 7.6072

Width of the Substrate,

ωs = 6h + ω 3

= 10.2

Length of the Substrate

LS = 6h + L 4

= 15.2

Length of the Ground

L_g = L+6h 5

= 10.2

Width of the Ground

L_g = ω +6h 6

= 15.2

Where,

The parameters are as follows:

c is light velocity,

f0 is resonant frequency,

εr is relative permittivity,

εr eff is the effective relative permittivity,

h is the substrate height, and

W is the substrate width.

TABLE 2: DIMENSIONS OF PROPOSED ANTENNA

Name of the parameters	Length
Length of the Substrate (Ls)	15.2mm
Width of the Substrate (Ws)	10.2mm
Length of the Patch (Lp)	7.6mm
Width of the Patch (Wp)	5.1mm
Relative permittivity of the substrate (FR4), εr	4.4mm
Height of the Substrate (H_s)	1.6mm
Length of the Feedline (L_f)	-3.8mm
Width of the Feedline (W_f)	2mm
Width of the Ground (Wg)	15.2mm
Length of the Ground (Lg)	10.2mm

B. Design CalculationOf ProposedAntenna

From the equation [1], the width of the patch, W_p= 5.1 mm.

From the equation [2], the length of the patch, L_p= 7.6 mm.

From the equation [3], the width of the substrate, W_s= 10.2 mm.

From the equation [4], the length of the substrate, L_s= 15.2 mm.

From the equation [5], the width of the ground, W_g= 10.2 mm.

From the equation [6], the length of the ground ,L_g= 15.2 mm.

Width of the feed line, W_f= 2 mm.

Length of the feed line, L_f = -3.8mm.

Height of the substrate, H_s=1.6 mm.

Relative permittivity of the substrate (FR4), εr= 4.4.

 DOI : 10.35291/2454-9150.2024.0332

ISSN : 2454-9150 Vol-10, Issue-05, Aug 2024

IV. ANTENNA DESIGN AT 12 GHz

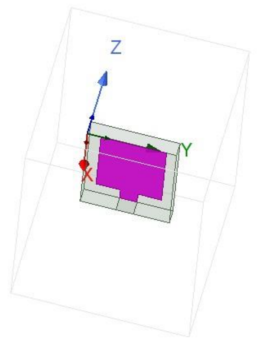

Fig.2: shows top view of proposed rectangular microstrip patch antenna

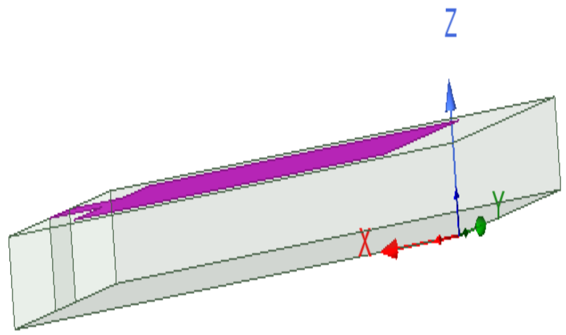

Fig.3: shows the side view of proposed rectangular microstrip patch antenna

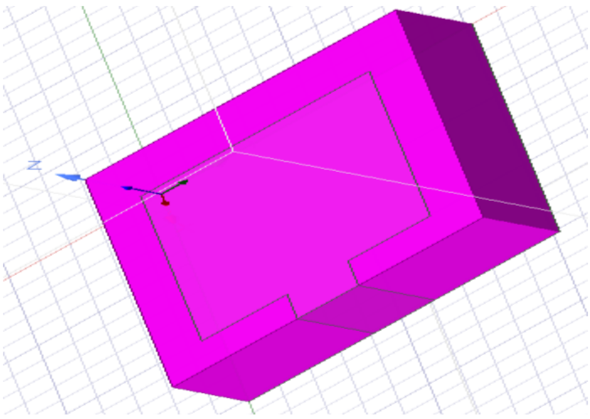

Fig.4: shows the 3D view of proposed rectangular microstrip patch antenna

V. RESULTS

A. *Result Procedure in Hfss Software*

Right-click on the result in Project Manager. Select Create Modal Solution Data Report. Select rectangular plot. Select the S parameter, then click S(1,1) and dB. Select "New Report" thenReturn Loss plot is shown.

Similarly, plots for VSWR, gain, directivity and radiation pattern are generated.

B. *Return Loss*

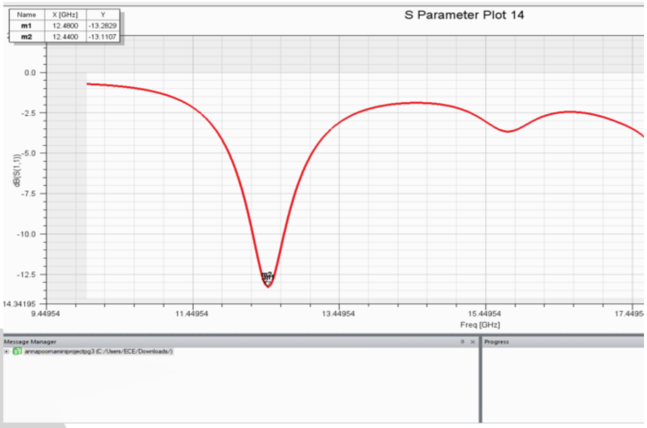

Fig. 5: Return loss of a rectangular microstrip patch antenna

Return loss is a measure of how much power is reflected back to the antenna due to an impedance mismatch. It's expressed in decibels (dB). Lower return loss indicates better impedance matching, meaning more power is being transmitted and less is being reflected. This rectangular microstrip patch antenna achieved a return loss of -13.2829 dB, as shown in Fig. 5.

C. *Gain Plot*

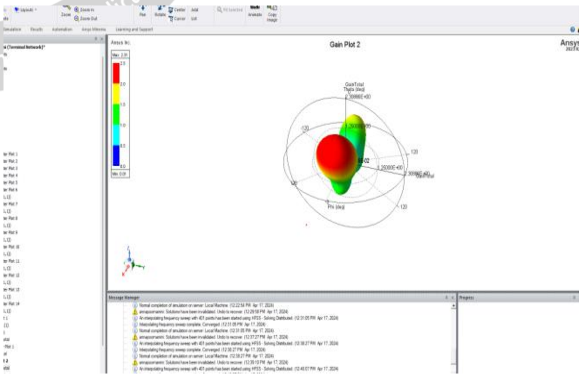

Fig. 6: Gain plot of a rectangular microstrip patch antenna

This rectangular microstrip patch antenna achieved a gain value of 50 dBi in a specific direction and can transmit or receive signals more effectively in that direction, as shown in Fig. 6. Gain is a measure of how much power is transmitted in a specific direction compared to an isotropic antenna, which radiates equally in all directions. Gain is usually expressed in dBi (decibels relative to an isotropic radiator). High gain in a specific direction means the

 DOI : 10.35291/2454-9150.2024.0332

ISSN : 2454-9150 Vol-10, Issue-05, Aug 2024

antenna can transmit or receive signals more effectively in that direction.

D. Directivity Plot

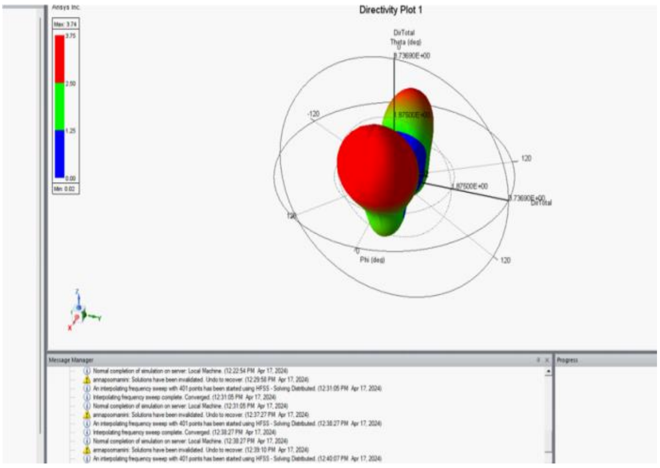

Fig. 7: Directivity of a rectangular microstrip patch antenna

This rectangular microstrip patch antenna achieved the directivity of 3.7400E that is shown in Fig 7. This indicates that more power is radiated in a specific direction, making the antenna more directional. Directivity is a measure of how concentrated the antenna's radiation is in a particular direction.

E. VSWR (Voltage Standing Wave Ratio)

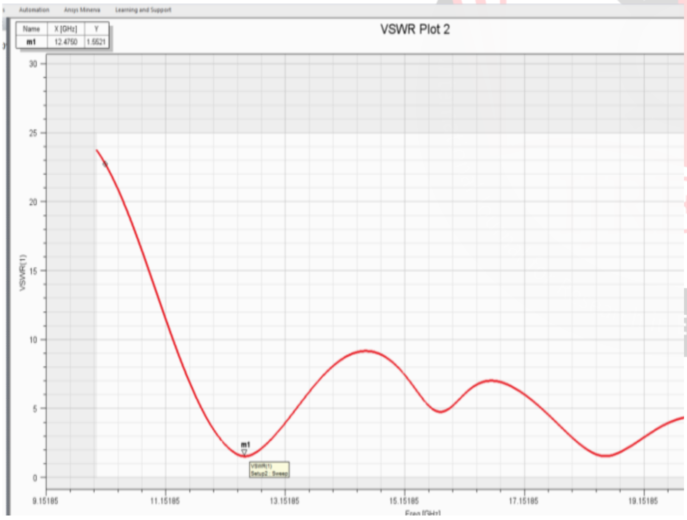

Fig. 8: VSWR (Voltage Standing Wave Ratio) of a rectangular microstrip patch antenna

VSWR is a measure of how well the antenna impedance matches the transmission line impedance. It is derived from S11. Lower VSWRs indicate better matching, with a value between 1 and 2. This rectangular microstrip patch antenna achieved a VSWR of 1.5521, as shown in Fig. 8.

F. Smith Chart

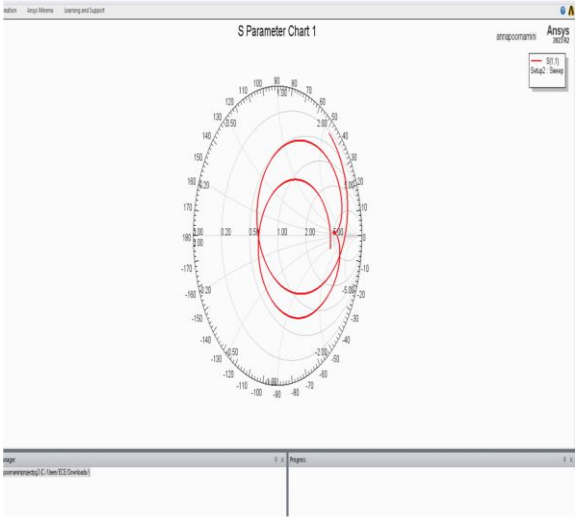

Fig. 9: Smith chart of a rectangular microstrip patch antenna

This rectangular microstrip patch antenna Smith chart is shown in Fig. 9 and represents the graphical representation used for solving problems with transmission lines and matching circuits. It plots complex reflection coefficients (S11), or impedance.

G. E-Field AND H- Field Radiation pattern

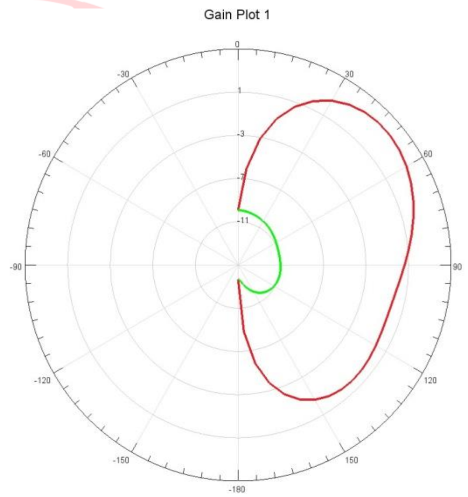

Fig.10: E-field and H- field radiation pattern of the antenna of rectangular microstrip patch antenna.

E-field (Electric Field) Radiation Pattern:

The red color line represents the electric field that is shown in Fig. 10 and represents the distribution of the electric field strength around the antenna. It indicates how the electric field radiates from the antenna, which is crucial for understanding the polarization and radiation characteristics.

H-field (Magnetic Field) Radiation Pattern:

The green color line represents the magnetic field line that is shown in Fig. 10, which represents the distribution of the magnetic field strength around the antenna. It complements

 DOI : 10.35291/2454-9150.2024.0332

the E-field pattern and is important for understanding the complete radiation characteristics of the antenna.

S.No.	Parameters	Range of Output
1	S-Parameters (Scattering Parameters)	-13.28 db
2	Voltage Standing Wave Ratio (VSWR)	1.55
3	Directivity Plot	3.74
4	Gain	2.31

TABLE: 3 PROPOSED ANTENNA PARAMETERS

VI. CONCLUSION

In conclusion, a major development in satellite communication technology has been made with the creation of a Ku-band rectangular microstrip patch antenna that operates at 12 GHz. This antenna maintains a VSWR under 2 (S11 parameter) of 1.5521for ideal impedance matching and efficient power transfer. It also precisely achieves a -10 dB return loss of -13.2829 dB to minimize reflections and maximize efficiency. Lastly, it ensures high radiation efficiency for efficient signal transmission and reception. Achieving these goals requires meticulous design and simulation to meet the stringent requirements of Ku-band communication systems.

REFERENCE

[1] Manimegalai ,Dr. I. Kalphana , DESIGN AND PERFORMANCE ANALYSIS OF A RMPA WITH VARIOUS SLOTS FOR SATELLITE COMMUNICATION, in (IJCRT) InternationalJournal of Creative Research Thoughts, Volume 12, Issue 7 July 2024 | ISSN: 2320-2882

[2] A.Manimegalai, Dr.I.Kalphana, “DESIGN AN ANALYSIS OF MICROSTRIP PATCH ANTENNA FOR SATELLITE COMMUNICATION”, in (IJCRT) International Journal of Creative Research Thoughts, Volume12, Issue 2 February2024|ISSN:2320-2882.

[3] Rashmitha R, Niran N, Abhinandan Ajit Jugale, Mohammed Riyaz Ahmed, “Microstrip Patch Antenna Design for Fixed Mobile and Satellite 5G Communications”, in Science Direct Procedia Computer Science 171 (2020) 2073–2079

[4] Mustafa Koçer, Mustafa Emre Aydemir, “Microstrip Patch Antenna Design for Military Satellite Communication”, in European Journal of Science and Technology Special Issue, pp. 142-147, September 2020

[5] Nishandhi, S., Reddy, D.Y., Ajith Kumar, R. (2022). “Designing of Microstrip Patch Antenna for Satellite Communication”, in Sivasubramanian A., Shastry, P.N., Hong, P.C. (eds) Futuristic Communication and Network Technologies VICFCNT 2020. Lecture Notes in Electrical Engineering, vol 792.

[6] Md. Sohel Rana1,2 , Sifat Hossain1 , Shuvashis Biswas Rana2 , Md. Mostafizur Rahman1 “Microstrip patch antennas for various applications: a review”, in Indonesian Journal of Electrical Engineering and Computer Science Vol. 29, No. 3, March 2023, pp. 1511~1519 ISSN: 2502-4752

[7] S.Manshari,S.KozielandL.Leifsson,"AWidebandCorrugated Ridged Horn Antenna With Enhanced Gainand Stable Phase Center for X- and Ku-Band Applications,"in IEEE Antennas and Wireless Propagation Letters, vol.18,no. 5,pp.1031-1035, May2019, doi:10.1109/LAWP.2019.2908290.

[8] A.NagaJyothi, T.Pavani P.Ayyappa Kumar, G.V.SaiSwetha, “Design of MicroStrip Stacked Patch Antenna in C-Band for Satellite and Radar Communications“, International Journal of Recent Technology and Engineering (IJRTE) ISSN:2277-3878(Online),Volume-8,Issue-1,May2019.

[9] Z. Yang, K. C. Browning and K. F. Warnick,"High-Efficiency Stacked Shorted Annular Patch Antenna Feed for Ku-Band Satellite Communications," in IEEE Transactions on Antennas and Propagation, vol. 64, no. 6, pp.2568-2572, June2016, doi:10.1109/TAP.2016.2551258.

[10] M.Khan,Z. YangandK. Warnick, "Dual-Circular-Polarized High-Efficiency Antenna for Ku Band Satellite Communication," in IEEE Antennas and Wireless Propagation Letters, vol.13,pp.1624-1627,2014,doi:10.1109/LAWP.2014.2345701.

[11] Jegan, A. Vimala juliet and G. Ashok kumar, "Multi band microstrip patch antenna for satellite communication," Recent Advances in Space Technology Services and Climate Change 2010 (RSTS & CC-2010), Chennai, India, 2010, pp. 153-156, doi: 10.1109/RSTSCC.2010.5712836.

[12] David M.Pozar, “Microstrip Antennas”, Proceedings of IEEE, Vol. 80, No. 1, January1992.

[13] G. M. Rebeiz and J. B. Muldavin, “RF MEMS switches and switch circuits,” IEEE MicrowaveMagazine, pp. 59-71,Dec. 2001.

[14] K. L. Wong and K. P. Yang, “Compact dual frequency microstrip antenna with a pair of bendslot,” Electronic Letters, vol. 34, pp. 225–226,1988.

[15] S. Maci and G. B. Gentillin, “Dual frequency patch antenna,” IEEE Antenna and Propagation Magazine, vol. 39, pp.13–17,1996.

[16] Action by the Commission November 29,2000, by Federal Report and Order/Further Notice of Proposed Rulemaking (FCC 00-418).Chairman Kennard, CommissionersNess, Powell and Tristani with Commissioner Fuchtgott-Roth.

[17] I.J.BahalandP.Bhartiya, Handbook of Microstrip Antenna, Artech House publishers, Dedham, MA, ISBN:9780890065136,2008.

[18] Balanies, C. A., Antenna Theory: Analysis &Design, 2nd edition, John Wiley & Sons, Inc.,1997.

[19] J.R.Jamesand P.S.Hall, Hand book of Microstrip Antennas, IEEE electromagnetic, waveseriespp.28,ISBN:9780863411502,1993.

[20] S. K. Dubey, S. K. Pathak and K. K. Modi, High Gain Multiple Resonance Ku-band Microstrip Patch Antenna, 978-1-4577-5/11/2011 IEEE [10]HFSS Electromagnetic simulator version 11.

